Electrolysis of potassium iodide solution

Introduction

Filter paper soaked in potassium iodide solution which also contains starch and phenolphthalein is placed on an aluminium sheet which forms one electrode of an electric circuit. The other electrode is used as a 'pen nib' to 'write' on the filter paper. When this electrode is made positive and the aluminium sheet negative, the writing is blue/black and when the polarity is reversed, the writing is pink.

This experiment should take around 20 minutes.

Equipment

Apparatus

- Eye protection
- Disposable gloves
- Aluminium (or other metal) sheet approximately 25 cm × 25 cm, but the size is not critical
- DC power supply (0 - 12 V)
- Leads and crocodile clips to connect to the power pack
- Filter papers, as large as possible to fit on the aluminium sheet

Chemicals

- Potassium iodide solution, 0.25 mol dm^{-3}, but the concentration is not critical, 100 cm^3
- Starch solution, 20 cm^3
- Sodium thiosulfate solution, approximately 1 mol dm^{-3}, but the concentration is not critical
- Phenolphthalein solution, 20 cm^3

Health, safety and technical notes

- Read our standard health and safety guidance here https://rsc.li/3WnP5l6
- Always wear eye protection
- Wash hands after the experiment, practitioners with skin irritation or cuts should wear disposable gloves.
- Aqueous potassium iodide is low hazard (see CLEAPSS Hazcard HC047b).
- Sodium thiosulfate solution is low hazard (see CLEAPSS Hazcard HC095a).
- Phenolphthalein solution is highly flammable (see CLEAPSS Hazcard HC032).

Procedure

1. Mix 40 cm^3 of potassium iodide solution with 10 cm^3 of starch solution. If the resulting solution has a blue colour (caused by contamination with iodine) add sodium thiosulfate solution dropwise until the solution becomes colourless.
2. Add 10 cm^3 of phenolphthalein solution. If the resulting solution has a pink colour (caused by contamination with alkali) add dilute hydrochloric acid solution dropwise until the solution just becomes colourless.
3. Thoroughly moisten three sheets of filter paper in this prepared mixture and place the papers onto the aluminium sheet one on top of the other. Moistening may be done using a dropping pipette or wash bottle.
4. Connect the aluminium sheet to the negative terminal of the power supply using a lead and crocodile clip. Connect a second lead to the positive terminal and switch on the power pack at between 6 V and 12 V.

5. Use the end of the positive lead to write or draw something on the top sheet of filter paper. The writing will appear blue/black, as iodine is discharged at the positive electrode and reacts with the starch to produce a blue/black complex. A corresponding pink line will appear on the lower filter paper in contact with the aluminium sheet, but this will not be visible. This is caused by the discharge of H^+ ions as hydrogen, which leaves an excess of OH^- ions in the solution. This alkaline solution turns the phenolphthalein pink.
6. Then switch the polarity of the electrodes so that the aluminium sheet becomes positive, and the free lead negative.
7. The writing on the upper sheet of filter paper now becomes pink. (There will also be a corresponding blue/black line on the lower filter paper.) The reason for using three filter papers in a stack is that this blue/black line would be visible through a single moist filter paper and obscure the paler pink line. Some teachers may wish to draw attention to the lines underneath the filter papers, others may wish to ignore them.

Extensions

If alternating current is used, a dotted line of alternating pink and blue/black is seen, provided the lead is drawn over the filter paper quickly enough. This is not as spectacular as might be expected, as the pink is much paler than the blue/black. Indicators other than phenolphthalein could be tried.

Theory

An aqueous solution of potassium iodide contains the following ions:
$K^+(aq)$ and $I^-(aq)$ from the solute $H^+(aq)$ and $OH^-(aq)$ from dissociation of the water.

At the positive electrode, $I^-(aq)$ and $OH^-(aq)$ are attracted to the positive electrode (anode) where iodide ions are converted to iodine: $2I^-(aq) - 2e^- \rightarrow I_2(aq)$

This occurs in preference to the thermodynamically favoured $4OH^-(aq) - 4e^- \rightarrow O_2(g) + 2H_2O(l)$ because of the much higher concentration of $I^-(aq)$ than $OH^-(aq)$

This iodine then forms a blue/black complex with the starch.
At the negative electrode, $H^+(aq)$ and $K^+(aq)$ are attracted to the negative electrode (cathode) where hydrogen ions are converted to hydrogen: $2H^+(aq) + 2e^- \rightarrow H_2(g)$
This occurs in preference to $K^+(aq) + e^- \rightarrow K(s)$ because the discharge potential is more positive.

This leaves an excess of $OH^-(aq)$ ions around the cathode, which turn phenolphthalein pink.

Notes

- A simpler explanation as to why hydrogen is discharged at the cathode is that if potassium (the alternative product) were discharged it would immediately react with water to return to K^+ ions, OH^- ions and hydrogen. Teachers might wish to use this explanation with some students.
- A sheet of newspaper placed below the aluminium sheet will reduce mess if the filter papers have been over-enthusiastically moistened.
- This experiment is suitable for a class experiment or science club activity if sufficient apparatus is available - a biscuit tin lid (or almost any metal sheet) can be used as an alternative to the aluminium sheet. Attaching a graphite pencil sharpened at both ends to the second lead gives a good, narrow line and also nicely shows the conductivity of graphite at the same time.

- The starch solution must be prepared shortly before use – it will not keep. It is prepared by mixing 1 g of soluble starch with a little deionised water to form a thin paste, then adding to this paste 80 cm^3 of boiling water. Stir the mixture, allow it to cool and dilute to 100 cm^3.
- To make phenolphthalein solution, dissolve 1 g solid phenolphthalein in 600 cm^3 of industrial methylated spirits and make up to 1 dm^3 with water.